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(54) HIGH-TENSILE STEEL CORD STRUCTURE.

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FR-A- 2 464 834
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Description

The inv ntion r lates to a steel cord adapted for th r inforc m nt f rubber articl s, and mor particularly to a st l cord adapted for th r inforc m nt of th breaker of rubber tires and to a steel cord having a high-tensile strength and high fatigue limit and to its use in passenger tires.

A steel cord adapted for the reinforcement of rubber articles usually comprises steel filaments having a carbon content lying between 0.60 and 1.10 per cent by weight (e.g. 0.70 %, 0.83 % or 0.96 %). A typical low-cost steel composition is : a minimum carbon content above 0.65 %, a manganese content between 0.40 % and 0.70 %, a silicon content between 0.15 % and 0.30 % and a maximum sulphur and maximum phosphorus content of 0.03 %, all percentages being percentages by weight.

Of particular importance is the carbon equivalent Ce which is defined by the following equation :

$$Ce = \%\,C + 0.3 \times (\%\,Mn - 0.40)$$

where % C is the carbon content in per cent by weight

% Mn is the manganese content in per cent by weight.

The carbon equivalent determines the reinforcing action. The greater its value the greater the theoretically attainable tensile strength R_m.

Other, more expensive, steel compositions, which comprise e.g. elements such as chromium, may also be used.

The diameter of the individual filaments adapted for the reinforcement of rubber articles lies in the range of 0.05 mm to 0.80 mm, preferably in the range of 0.05 mm to 0.50 mm.

The exact value depends upon the particular steel cord structure, on the particular use and on the desired mechanical properties.

The steel filaments are usually provided with a coating which promotes the adherence of said steel filaments to the rubber. Such a coating conveniently comprises copper, zinc, brass or ternary brass alloy, or a combination of two or more different layers thereof. The thickness of the coating ranges from 0.05 to 0.40 micron, preferably from 0.12 to 0.30 micron. The coating can also be present in the form of a chemical primer which ensures good rubber penetration and adhesion.

A lot of simple steel cord constructions have already been developed. Among these, the n x δ steel cord construction is a well known construction. It is formed by n steel filaments, conveniently of equal diameter δ, which are twisted around each other with a twist pitch s. n is an integer and may have the values 3,4 or 5.

A well known drawback of this n x δ steel cord structure is that full rubber penetration is impossible if each individual steel filament contacts the other steel filaments along their entire length.

This drawback has been remedied by mechanically forming or preforming the individual steel filaments in such a way that in the resulting n x δ steel cord structure the steel filaments do not longer contact each other along their entire length. This particular structure is known as a n x δ open cord (OC) or penetration cord. Such open steel cord structures are disclosed in BE-A-879656 and in NL-A-8005088

A parameter which is suitable to quantify this mechanical formation or preformation is the part load elongation, abbreviated as PLE. This part load elongation is defined as the increase in length of the gauge length between a tension of 2.5 N and 50 N and may be expressed as a percentage of the original gauge length. The PLE-value predicts the behaviour of the steel cord when it is wound from a creel in a calendering installation under a certain pay-off tension. The greater the PLE-value the greater the remaining openness during this unwinding and hence, the better the rubber penetration during the subsequent tire manufacturing. The smaller the PLE-value the quicker the cord closes under the pay-off tension and the smaller the chance for full rubber penetration during the tire manufacturing.

GB-A-2.081.765 discloses a steel cord adapted for the reinforcement of the breaker of rubber tires. The steel cord consists of three steel filaments (3 x δ construction), which are twisted around each other with a predetermined twist pitch and which have a diameter δ. The part load elongation (PLE) lies between 0.2 and 1.2 % and the diameter δ lies between 0.12 and 0.4 mm.

Up to now all the n x δ cords in open versions have been treated in the same way, that is, no distinction has been made between them regarding the preformation to be applied to the different n x δ cords. How ver, the inv ntor has discovered that a distinction has to be mad between a 4 x δ open cord r a 5 x δ pen cord and a 3 x δ open cord.

Th most commonly used open cords are 4 x δ and 5 x δ cords. They are based on filaments having a diam t r δ ranging from 0.22 t 0.25 mm. The inv ntor has discovered that a drawback of th se 4 x δ and 5 x δ steel cords is th ir high PLE-value. Tir analysis has proved that 4 x 0.25 and 5 x 0.25 open steel cords

show good rubber p n tration only when the PLE-value is great r than 0.50 - 0.60 %. How v r, this giv s a more irregular cord resulting in lower tensile and compression modulus causing lower ste ring and cornering properti s of th tir as a final result.

It is an object of the pr sent inv ntion t avoid th drawbacks of th prior art constructions.

It is another object of the present invention to provide a 3 x δ steel cord construction which has enhanced tensile strength properties.

Another object of the present invention is to provide a steel cord with full and uniform rubber penetration independent of the pay-off tension used in the tire building process.

According to a first aspect of the present invention there is provided a steel cord adapted for the reinforcement of the breaker of rubber tires, said steel cord consisting of three steel filaments which are twisted around each other with a predetermined twist pitch and which have a diameter δ, said steel cord having a part load elongation between 0.2 and 0.45 % and by a high tensile strength R_m and by a diameter δ in the range of 0.27 mm to 0.35 mm.

In a preferable embodiment the steel cord according to the invention has a super high tensile strength R_m.

In a most preferable embodiment the steel cord according to the invention has a twist pitch of 14 mm.

The twist pitch is the axial distance required to make a 360 degree revolution of any steel filament in the steel cord.

A steel cord has a high tensile strength if the tensile strength R_m is more than

$$2250 - 1130 \log d \ (N/mm^2) \qquad (1)$$

wherein d is the diameter in mm of the individual steel filaments.

A super high tensile steel cord has a tensile strength R_m which is at least 6 per cent greater than the value according to formula (1).

More detailed values will be given below.

A 3 x δ steel cord adapted for the reinforcement of rubber tires consists of three filaments having a diameter between 0.27 and 0.35 mm. These values are needed in order to have sufficient stiffness. They are higher than the diameters used in 4 x δ and 5 x δ open cords for breaker reinforcement. These higher values give as a result that relatively low PLE-values (between 0.35 and 0.50) remain optimal for rubber penetration even when a prestress of 20 N is applied.

According to a second aspect of the present invention there is provided a rubber product comprising a steel cord according to the first aspect of the present invention. Such a rubber product may be a rubber hose, a rubber belt or a rubber tire. However, the steel cord according to the first aspect of the present invention is preferably used in a passenger tire.

The invention will now be described with reference to the accompanying drawings wherein

- figure 1 represents a cross-section of a steel cord according to the invention ;
- figure 2 represents a longitudinal view of a steel cord according to the invention ;
- figures 3, 4 and 5 represent different ways of manufacturing a steel cord according to the invention.
- figure 6 represents a use of steel cords according to the invention.

Figures 1 and 2 represent a steel cord 10 according to the invention. The three individual steel filaments 1 do not contact each other along their length and, as a consequence, allow full rubber penetration.

A high tensile steel filament may be manufactured in the following way. Wire rod is cold drawn from a start diameter d_s between 5.5 and 6.5 mm to a steel wire with an intermediate diameter d_i which lies between 0.80 and 2.50 mm. The steel wire is then patented, i.e. heated to a temperature above 900 °C followed by an immersion in a quench-transformation bath (e.g. a molten lead bath) at a temperature between 450 and 700 °C and by a cooling to ambient temperature. The steel wires are plated with brass and are subsequently wet drawn from the intermediate diameter d_i to steel filaments having a final diameter d_f which lies between 0.05 and 0.80 mm.

The exact value of the tensile strength R_m depends, among others, on

- the final diameter,
- the reduction during the wet drawing operation, and on
- the steel composition.

As a matt r of xampl tabl 1 gives for differ nt steel filam nts th int rmediate diam t r d_i, the final diamet r d_f, th reduction according to th equation

$$\epsilon = 2 \ln \frac{d_i}{d_f} \qquad (2)$$

the percentage reduction in surface R according to the equation

$$R = \frac{d_i^2 - d_f^2}{d_i^2} \times 100 \qquad (3)$$

and the achieved high tensile strength R_m.

Table 2 gives the same data but for a super high tensile R_m.

All these steel filaments had a low-cost steel composition with a carbon equivalent Ce of 0.875 % and a carbon content % C between 0.80 and 0.85 per cent by weight.

TABLE 1

HIGH TENSILE STEEL FILAMENTS				
d_i (mm)	d_f (mm)	ϵ	R (%)	R_m (N/mm²)
1.50	0.28	3.36	96.5	3100
1.50	0.30	3.21	96.0	3000
1.50	0.32	3.09	95.4	2900
1.62	0.35	3.06	95.3	2850

TABLE 2

SUPER HIGH TENSILE STEEL FILAMENTS				
d_i (mm)	d_f (mm)	ϵ	R (%)	R_m (N/mm²)
1.69	0.28	3.60	97.3	3400
1.76	0.30	3.54	97.1	3350
1.82	0.32	3.48	96.9	3250
1.95	0.35	3.44	96.8	3220

The steel cord according to the invention may be manufactured by a conventional tubular strander 30 (figure 3) or by a conventional double twister 40 (figure 4) or 50 (figure 5).

Referring to figure 3 two pay-off bobbins 32 are positioned in stationary cradles at the inside of the drum 31 and one pay-off bobbin 33 is positioned outside the drum 31. While the drum 31 is rotating, the filaments 1 are drawn from the bobbins 32, 33 and form the cord 10 at the cabling die 34. The formed cord 10 is wound on the bobbin 35. The preformation of the cords is given at 36 just before the cabling die 34.

Referring to figure 4 three pay-off bobbins 44 are located inside the rotatable flyer 41 of a double twister 40. The steel filaments 1 are drawn from the bobbins 44, pass over a preformer 46 and through a die 47, are given a first twist and pass over a first pulley 42 to the flyer 41, subsequently over a second pulley 43 after which they are given a second twist. The formed cord 10 is wound upon a bobbin 45 which is located outside the double twister 40.

A double twister may also be used in another way. This is represented on figure 5. Three pay-off bobbins 54 are located outside the double twister 50, whereas the winding unit 55 is located inside the flyer 51. The steel filaments ar drawn from th bobbins 54, pass over a preforming plat 56 and through a di 57, converge towards each oth r and ar giv n a first twist, then they pass ver a pull y 53, a flyer 51 to a pull y 52, aft r which th y ar giv n a second twist. Th formed cord 10 is subsequently wound upon the winding unit 55.

In a pr f rabl mbodim nt of th double twisters 40 and 50 th pull ys 42, 43 r sp. 52, 53 allow the twists to travel along their path.

Th rubber products according to th second aspect of the present invention may be obtained by introducing a plurality of steel cords according to a first aspect of th invention in an unvulcanized rubber composition and then vulcanizing the whole. In general, the steel cords are firstly impregnated in an adhesion rubber composition. Such adhesion rubber conveniently comprises 40 to 70 parts of carbon black per 100 parts of rubber, 2 to 6 parts of coumarone resin, 4 to 12 parts of Zinc oxide and 1 to 5 parts of sulphur, and further no more than 10 parts in total of antioxidant or accelerator or other agents, all parts being parts by weight.

In the case the steel cords are used as reinforcement of a belt or breaker ply of a passenger tire, the steel cords are laid side by side to form a foil of one or more superposed layers of cords and this foil is covered on either side with a foil of unvulcanized adhesion rubber which enters between and, thanks to their openness, into the cords. The whole composite is cut into strips and the result is a strip of cord pieces, lying side by side in one or more superposed layers, and impregnated with unvulcanized adhesion rubber.

Figure 6 represents a view of how the steel cords according to the invention with a PLE-value of 0.40 are used in the breaker of a passenger tire. There are two belt or breaker plies. In each ply the steel cords 10 are parallel to each other and form a certain angle to the direction of movement of the tire. As may be easily seen, the steel cord still has an openness which is great enough to allow rubber penetration notwithstanding the use of a pay-off tension in the calendering installation.

Table 3 mentions some values of "ends per dm" and some "packing factors" when the steel cord according to the invention is used in different types of passenger tires.

"Ends per dm" is the number of steel cords used per dm of ply length.

The "packing factor" is equal to the maximum diameter of the cord in mm multiplied by the "ends per dm".

TABLE 3 : USE OF THE STEEL CORD ACCORDING TO THE INVENTION IN PASSENGER TIRES

	3x0.28 PLE=0.20 SHT	3x0.28 PLE=0.40 SHT	3x0.30 PLE=0.20 SHT	3x0.30 PLE=0.40 SHT
tire: 165SR13				
ends per dm	77-91	77-91	64-76	64-76
packing factor	48-57 %	73-87 %	49-59 %	69-82 %
tire: 175SR14				
ends per dm	64-143	64-91	53-92	53-69
packing factor	40-89 %	61-87 %	41-71 %	57-82 %
tire: 185SR14				
ends per dm	70	70	59	59
packing factor	44 %	67 %	45 %	63 %
tire: 195SR14				
ends per dm	77-78			
packing factor				

The mentioned values generally do not indicate the limits of possible realisations. They only mean that it is possible to realize a specified type of passenger tire with the mentioned parameters.

A 3 x δ super high tensile (SHT) open cord (OC) adapted for the reinforcement of a breaker ply for a passenger tires has been compared with other existing steel cord constructions which are also suitable for the reinforcement of a breaker ply for passenger tires.

The stiffness in rubber has been measured by the well known three-point-bending test.

The rubber penetration is the amount of air passing through a rubber block (224 mm long, 15 mm high, and 265 mm wide), in which four identical steel cord constructions are embedded, at a 4 bar air pressure difference.

A pretension of 20 N is also applied to check the processing influence of the pay-off tension.

The fatigue limit has been determined by the Hunter test.

Table 4 summarizes the comparative results.

TABLE 4 - COMPARISON WITH OTHER CORDS

	INVENTION		PRIOR ART			
	3x0.30 OC-SHT s=16mm	3x0.28 OC-SHT s=14mm	2+2x0.25 s=14mm	4x0.25 OC s=14mm	2x0.30 HT s=14mm	2+1x0.30 HT s=16mm
tensile strength (N)	678	565	530	530	445	685
cord diameter (mm)	0.73	0.65	0.66	0.62	0.60	0.77
max. cord diameter (mm)	1.09	0.96	0.73	0.91	0.63	0.85
linear density (g/m)	1.68	1.47	1.55	1.56	1.12	1.67
cord stiffness in rubber (N.mm^2)	258	207	251	178	200	408
rubber penetration (l/h) at 4 bar	0	0	0	0	0	0
- with 20 N tension to the cord	0	0	0	20	0	0
fatigue limit in rubber (N/mm^2)	950	1000	630	980	1050	600
PLE (%)	0.37	0.40	0.14	0.50	0.16	0.14

The steel cord according to the invention has a high tensile strength and a high stiffness in rubber, it allows full rubber penetration even in prestressed condition and maintains a high level of fatigue.

A 4 x 0.25 open cord with a PLE-value of 0.50 % has only full rubber pen tration wh n it is not put under t nsion. As indicated in table 4 a t nsion of 20 N results in incomplete rubber penetration. This is due to the fact that cords comprising filam nts with a diameter between 0.23 and 0.25 mm are less stiff than cords comprising filaments with a diam t r betw n 0.27 and 0.35 mm.

All the other prior art constructions mentioned in table 4 allow full and uniform rubber penetration even when put under a tension of 20 N, but

- a 2 + 2 x 0.25 cord has a low fatigue limit,
- a 2 + 1 x 0.30 cord also has a low fatigue limit,
- a 2 x 0.30 cord has a low tensile strength.

In order to optimize the twist pitch s four steel cords according to the invention with different values of the twist pitch s have been compared with each other.
Table 5 summarizes the results. The values of compression strength and compression modulus are relative values since the absolute values are of no importance.

TABLE 5 - INFLUENCE OF THE TWIST PITCH

3 x 0.28 OC-SHT PLE = 0.40 %

twist pitch s (mm)	10	12.5	14	16
breaking load (N)	578	581	586	585
breaking strength R_m (N/mm^2)	3071	3088	3117	3118
elongation at fracture (%)	3.5	3.4	3.3	3.0
compression strength	100	126.1	159.4	146.5
compression modulus	100	146.8	175.9	163.3

The optimal value of the twist pitch s is 14 mm because of its higher compression strength and compression modulus.

Claims

1. A steel cord adapted for the reinforcement of the breaker of rubber tires, said steel cord consisting of three steel filaments which are twisted around each other with a predetermined twist pitch and which have a diameter δ (3 x δ construction), said steel cord having a part load elongation between 0.2 and 0.45%, a high tensile strength R_m and a diameter δ lying in the range of 0.27 to 0.35 mm.

2. A steel cord according to claim 1, characterized by a super high tensile strength R_m.

3. A steel cord according to claim 1 or 2, characterized in that said twist pitch is 14 mm.

4. A rubber product characterized in that said rubber product comprises a steel cord according to claim 1.

5. A rubber passeng r tir having a width between 155 mm and 195 mm and a rim between 12 inch (305 mm) and 15 inch (381 mm) and comprising one to four belt plies, characterized in that said belt pli s are reinforced with a steel cord according to claim 1 in such a way that said belt plies have 50 to 144 ends per dm and a packing factor between 40 and 90 %.

Patentansprüche

1. Stahlseil zum V rstärken der Einlage von Gummireif n, w bei das Stahls il aus dr i Stahldrähten best ht, di mit einer vorgegeben n Windungsst igung um inander g wund n sind und inen Durchmesser δ (3 xδ-Konstruktion) haben, und wobei das Stahlseil eine Teillastlängung zwischen 0,2 und 0,45%, eine Hoch-Zugfestigkeit R_m und einen Durchmesser δ im Bereich von 0,27 bis 0,35 mm hat.

2. Stahlseil nach Anspruch 1, **gekennzeichnet** durch eine Super-Hoch-Zugfestigkeit R_m.

3. Stahlseil nach Anspruch 1 oder 2, **dadurch gekennzeichnet**, daß die Windungssteigung gleich 14 mm ist.

4. Gummiprodukt, **dadurch gekennzeichnet**, daß das Gummiprodukt ein Stahlseil gemäß Anspruch 1 enthält.

5. Gummireifen für Passagierfahrzeuge mit einer Breite zwischen 155 mm und 195 mm sowie einem Felgenmaß zwischen 12 Zoll (305 mm) und 15 Zoll (381 mm), umfassend eine bis vier Gürtellagen, **dadurch gekennzeichnet**, daß die Gürtellagen mit einem Stahlseil gemäß Anspruch 1 verstärkt sind, derart, daß die Gürtellagen 50 bis 144 Enden pro dm und einen Packfaktor zwischen 40 und 90% haben.

Revendications

1. Câblé d'acier destiné à l'armature de la nappe sommet de pneumatiques de caoutchouc, le câblé d'acier étant formé de trois filaments d'acier qui sont retordus mutuellement avec un pas prédéterminé de torsion et qui ont un diamètre δ (construction 3 x δ), le câblé d'acier ayant un allongement sous charge partielle compris entre 0,2 et 0,45 %, une résistance élevée à la traction R_m et un diamètre δ compris entre 0,27 et 0,35 mm.

2. Câblé d'acier selon la revendication 1, caractérisé par une résistance extrêmement élevée à la traction R_m.

3. Câblé d'acier selon la revendication 1 ou 2, caractérisé en ce que le pas de torsion est de 14 mm.

4. Produit de caoutchouc caractérisé en ce qu'il contient un câblé d'acier selon la revendication 1.

5. Pneumatique de caoutchouc pour véhicule de transport de passagers, ayant une largeur comprise entre 155 et 195 mm et une jante comprise entre 305 et 381 mm (12 et 15 pouces), et comprenant une à quatre nappes de ceinture, caractérisé en ce que les nappes de ceinture sont armées par un câblé d'acier selon la revendication 1 de manière que les nappes de ceinture possèdent 50 à 144 extrémités par décimètre avec un facteur de remplissage compris entre 40 et 90 %.

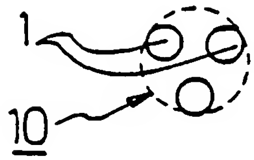

FIG.1

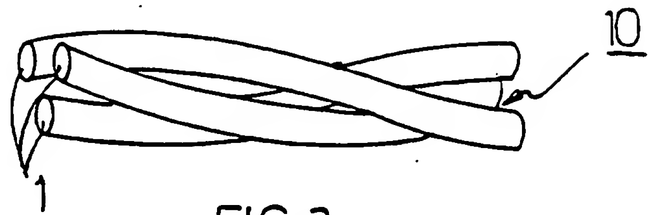

FIG.2

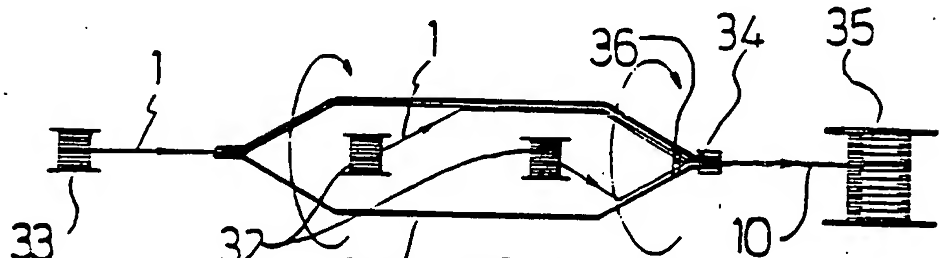

FIG.3

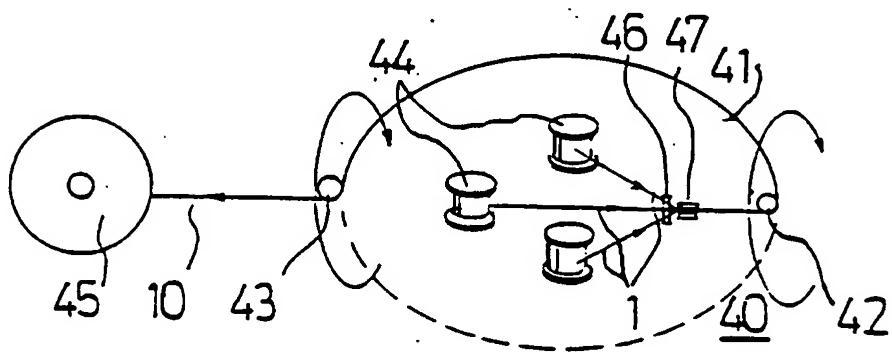

FIG.4

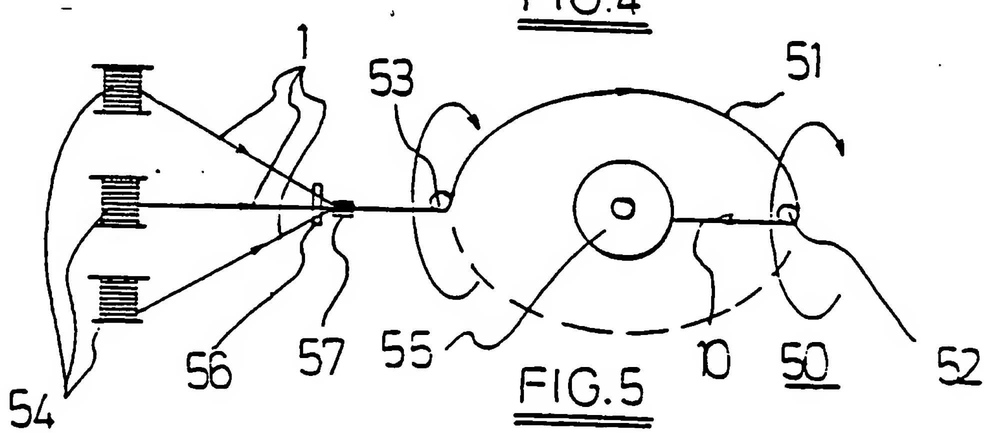

FIG.5

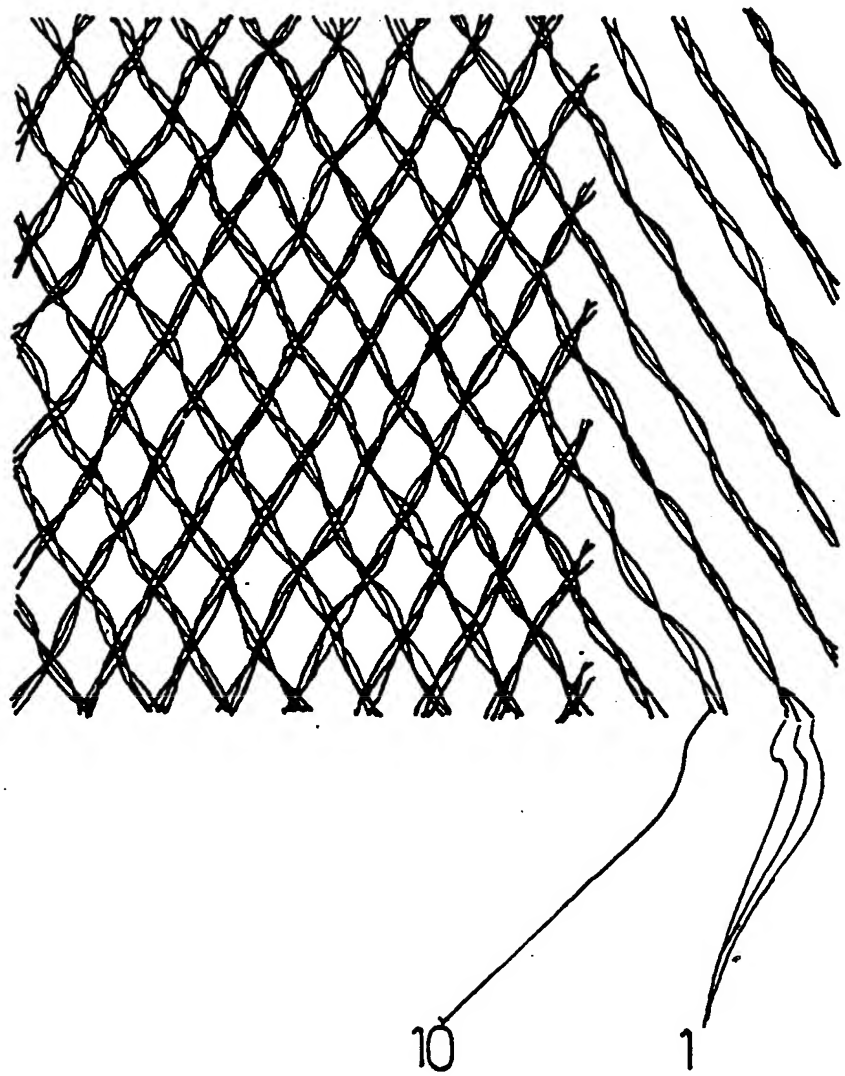

FIG. 6